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Use of Anticoagulant Rodenticides in Single-Family Neighborhoods Along an Urban-Wildland Interface in California

Urbanization poses many threats for many wildlife species. In addition to habitat loss and fragmentation, non-target wildlife species are vulnerable to poisoning by rodenticides, especially acutely toxic second generation anticoagulant rodenticides (SGARs). Although such poisonings are well documented for birds and mammals worldwide, the pathways by which these widely available compounds reach non-target wildlife have not been adequately studied, particularly in urban landscapes. Long-term studies of wild carnivores in and around Santa Monica Mountains National Recreation Area, a national park north of Los Angeles, have documented >85% exposure to anticoagulant rodenticides among bobcats, coyotes, and mountain lions. To investigate potential mechanisms of transfer of chemicals from residential users of rodenticides to non-target wildlife in the Santa Monica Mountains in Los Angeles County, California, we distributed surveys to residents in two study areas on the north (San Fernando Valley) and south (Bel Air-Hollywood Hills) slopes of these mountains. We assessed knowledge of residents about the environmental effects of rodenticides, and for information about individual application of chemicals. We asked for the same information from pest control operators (PCOs) in both study areas. Forty residents completed the survey in the San Fernando Valley area, and 20 residents completed the survey in Bel Air-Hollywood Hills. Despite the small number of total responses, we documented a number of important findings. Homeowners (as opposed to gardeners or PCOs) were the primary applicators of rodenticides, predominantly SGARs, and awareness of the hazards of secondary poisoning to wildlife was not consistent. Some residents reported improperly applying rodenticides (e.g., exceeding prescribed distances from structures), and in one instance a respondent reported observing dead animals outside after placing poison inside a structure. Improper application of SGARs that ignores label guidelines occurs in neighborhoods along the urban-wildland interface, thereby providing a transmission pathway for chemical rodenticides to reach native wildlife. Moreover, the responses suggest that even on-label use (e.g. placing poisons inside) can create risk for non-target wildlife.

Keywords

Anticoagulant, non-target species, urban carnivores, secondary poisoning, second generation anticoagulant rodenticides

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INTRODUCTION

Rodent control is a widespread activity in the U.S. Of the \$90 million per year that residents spend on rodent control products, 90% of those products are in the dry bait category, such as anticoagulants (U.S. Environmental Protection Agency 2006). Genetic resistance to the first-generation anticoagulant rodenticides (e.g., warfarin) has led to development of a second generation of anticoagulant pesticides that are used against small mammal pests of households and agricultural crops (i.e., Norway and black rats, *Rattus norvegicus* and *R. rattus*, and house mice, *Mus musculus*) (Hadler and Buckle 1992). Second-generation anticoagulant rodenticides (SGARs; e.g., brodifacoum, bromadiolone, difethialone, difenacoum, and flocoumafen) are faster acting, more toxic, and more persistent in the environment than their first generation predecessors (Hadler and Buckle 1992; Whisson 1996). Although successful at controlling rodent pests, SGARs globally also contribute to non-target species mortality, such as in New Zealand (Alterio 1996), France (Lambert et al. 2007; Berny and Gaillet 2008), Britain (McDonald et al. 1998; Shore et al. 2003), and Canada (Thomas et al. 2011). In the US, many non-target species have been poisoned by SGARs (Stone et al. 1999; Way et al. 2006; Riley et al. 2007; Uzal et al. 2007; U.S. Environmental Protection Agency 2008; Albert et al. 2010).

Rodents that ingest SGARs may display behaviors that facilitate the ability of predators to capture them (Cox and Smith 1990). Internal hemorrhage greatly affects limb movement, thereby increasing lethargy and decreasing mobility of poisoned rodents. Cerebral hemorrhages can interrupt thigmotaxis, a behavioral mechanism that would normally lead an animal to maximize use of available cover (Cox and Smith 1990; Brakes and Smith 2005). Therefore, we might expect poisoned rodents to be at greater risk of being captured as prey than healthy animals. In turn, opportunistic predators may be at a particular risk because they seek prey that can be caught easily. Consumption of either prey or carcasses contaminated with rodenticides may lead to poisoning of a predator (Brakes and Smith 2005; Rattner et al. 2011). SGARs can even affect wildlife as a result of consuming contaminated invertebrates, contaminated soil, or baits that have been removed from bait stations by rodents (Dowding et al. 2010). Even if products are used inside buildings, poisoned rodents may travel outside where predators could catch them (Stone et al. 1999).

Non-target species that have been documented as being exposed to SGARs in the United States and Canada include barn owl, barred owl, and great horned owl (Albert et al. 2010), gray squirrel, raccoon, white-tailed deer, and red-tailed hawk (Stone et al. 1999), bobcat, coyote and mountain lion (Way et al. 2006; Riley et al. 2007; Uzal et al. 2007), and red fox, striped skunk, and raccoon (U.S. Environmental Protection Agency 2008). In New York State during a 27-year period brodifacoum was involved in 84% of the poisoning cases evaluated (Stone et al. 1999). In one instance, the source of the exposure was determined to be brodifacoum applied in barns and sheds where an owl subsequently was found nearly dead from exsanguination caused by a small laceration on a toe (Stone et al. 1999). This example documents that even though rodenticides were used inside buildings, poisoned rodents traveled outside where predators could catch them. Secondary poisoning — where a non-target species consumes a poisoned target species — caused by these compounds has also been linked to increased disease prevalence, specifically increased susceptibility to parasitic mange in bobcats (Riley et al. 2007).

Urban carnivores are predisposed to secondary poisoning because of habitat use in proximity to residential neighborhoods where these poisons are used (Riley et al. 2003; Gehrt and Riley 2010). In fact, besides road kills, poisoning by rodenticides has been identified as a cause of mortality for urban coyote (*Canis latrans*; Gehrt and Riley 2010), bobcat (*Lynx rufus*; Riley et al. 2010), San Joaquin kit fox (*Vulpes macrotis*; Cypher 2010), and mountain lion (*Puma concolor*; Beier et al. 2010). Others suspect that SGARs may be used to intentionally poison wildlife (Way et al. 2006). The prevalence and severe consequences of SGAR intoxication warrant further investigation.

Use of rodenticides in the agricultural conditions in Europe has been investigated through user surveys (Tosh et al. 2011). These results indicated that users were generally aware of the effects on non-target species, but did not always follow all best practices for application (Tosh et al. 2011). In contrast, few residential users in a previous study in California were aware of non-target species impacts (Morzillo and Mertig 2011a). The application practices of residential users on the urban–wildland interface are not well described, which motivated this study.

We investigated rodent control in a region where secondary poisoning of carnivores has occurred (Riley et al. 2007; Gehrt and Riley 2010). Our objective was to determine potential starting points of pathways through which rodenticides applied at single-family residences eventually could reach non-target wildlife. In other words, we asked, where might anticoagulant rodenticides enter the “natural” environment? Besides describing rodenticide use, we sought to confirm that one SGAR pathway to non-target species is through improper applications by homeowners. SGAR label instructions specify that the baits be applied “inside and along the outside walls of buildings” (U.S. Environmental Protection Agency 1998). We also assessed user knowledge of non-target impacts and compared use of rodent control methods by residents with those of licensed Pest Control Operators (PCOs).

METHODS

This research was a senior-level student-directed project as part of the Environmental Science Practicum at the University of California, Los Angeles (UCLA). There, seniors pursue research projects for an off-campus client, in this instance, the National Park Service at Santa Monica Mountains National Recreation Area (SMMNRA). For purposes of student training, the class was separated into two groups, each with its own study area adjacent to SMMNRA.

Study Areas

Each study area represents an area of urban–wildland interface where residential neighborhoods overlap with habitat of native wildlife, including mountain lions, bobcats, and coyotes. Extensive exposure to anticoagulant rodenticides has been reported within and surrounding SMMNRA (Riley et al. 2003; Riley et al. 2007; Gehrt and Riley 2010). Morzillo and Mertig (2011a, b) evaluated factors affecting use of chemical rodenticides by homeowners in an area adjacent to the western boundary of the current study area.

San Fernando Valley (SFV). This study area contained low- to medium-density residential development, as well as some commercial development and golf courses (Figure 1).

The 101 and 405 Freeways border the study area on the north and east. We further defined the northern boundary of the study area as Ventura Boulevard because it marks the northern (inland) extent of the Santa Monica Mountains.

Bel Air-Hollywood Hills (BA-HH). This study area included the coastal slope of the Santa Monica Mountains south of the 405 Freeway and the 101 Freeway intersection (Figure 1). This area is characterized by highly fragmented open space interspersed with residential development in canyons (Beverly Glen, Benedict, Coldwater, Laurel) and on ridgelines (e.g., Bel Air, Beverly Hills, and Hollywood Hills). Open space lies to the west and Griffith Park (largest natural park in the city of Los Angeles; 1,744 ha) is found to the east. This area is almost exclusively low-density residential with many large homes.

Figure 1. Study areas in San Fernando Valley and Bel-Air to Hollywood Hills. Fliers were distributed to residences indicated by squares.

Survey Design

We developed a series of questions to collect information about rodenticide use, application, and knowledge about related environmental effects (see Appendix A). We employed our survey using an online questionnaire. This method was used because of its low-cost advantage, as well as ease of accessibility, delivery, and response times (e.g., Couper 2009; Poole and Loomis 2009). We acknowledge that several concerns, such as coverage error and potential for response inconsistencies have been linked to use of internet questionnaires (e.g., Couper 2009; Poole and Loomis 2009).

The first part of the survey included an introduction to inform participants of the purpose of the survey, consent information, a description about how the data would be used, and an estimate of the time it would take to complete the survey (Warwick and Lininger 1975). The next several sections investigated if rodenticides were used, products used, target species, application process, and awareness of non-target effects. To ensure recall of the type of rodenticide used, we provided a list of brand names with photographs. Respondents therefore had both the names of the products and a visual reminder of the color and design of the packaging to make their choices about use of chemical rodenticides. We also asked general demographic questions including income, property size, education, age, and ethnicity. All questions in the survey except date of birth were closed questions. Each question was contained on its own webpage to avoid confusion. Finally, the survey ended with a “thank you” for the participants and an invitation to enter into a random drawing for a \$50 gift card. The UCLA Institutional Review Board granted the use of human subjects (IRB Exempt Protocol #10-065).

Recruitment of Participants

In March 2010, we contacted Home Owners Associations (HOAs) and Residents Associations for assistance with recruiting resident participants for the online survey. In SFV, two associations agreed to participate; one announced the study using a digital flier, and the other in a digital newsletter. For associations where no residents responded to the electronic solicitation, we also distributed fliers door-to-door (see Appendix B). All recruited participants were limited to occupants of single-family residences.

We placed fliers either on the door handle or on the doormat, with the UCLA seal and title of the project clearly visible. When homeowners were present, we briefly explained the project and invited them to participate. Fliers were placed near the gate or the security keypad of gated properties.

In SFV, we focused on the areas closest to SMMNRA (Riley et al. 2006). This area included areas within Encino, Woodland Hills, Calabasas, and Tarzana. For each of the areas, we randomly selected grids from the Thomas Guide Map, 2007 Edition; each grid contained 250–350 homes. In BA-HH, we used Google Earth to create a quarter-mile-square grid within this study area. We used a random number generator to select nine grid cells within BA-HH (Figure 1). If a selected area lacked residential areas, we used the random number generator to select replacement areas until we had 9 suitable areas. We then walked door-to-door and distributed fliers. In SFV, we delivered 1,200 fliers. In BA-HH we delivered 460 fliers. The difference in the number of fliers is attributed to variation in building density.

Pest Control Operator Interviews

We interviewed managers of pest control operators (PCO) to obtain information about the types of chemicals used, techniques used to apply chemicals, distribution of these chemicals (i.e., where and when they were used), as well as the primary reasons that homeowners retained their services (see Appendix C). We used a phone directory to compile a list of PCOs for each study area and randomly selected companies to sample. We also initiated contacts to any PCO reported by respondents to the online survey.

RESULTS

Survey of Residents

In SFV, 53 people completed online survey; 13 of these responses did not qualify for further analysis. In BA-HH, we received response from 21 residents; one of these responses did not qualify for further analysis. The age of respondents between the two areas did not differ (Student's T test, $p < 0.80$; average age = 55) nor did their ethnicity (Chi-square, $p < 0.27$; overall 95.5% white) or education level (Chi-square, $p < 0.83$; overall 87.9% with bachelor's degree or more).

Figure 2. Target species for homeowner rodent control for two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents could select more than one target species. Several responses were volunteered (raccoons, snakes and rabbits).

In SFV, 65% of respondents used some form of rodent control on their property within the last year, as did 75% in BA-HH. Rats were the most commonly cited target species in both locations, followed by mice and gophers in BA-HH, and gophers and moles in the SFV (Figure 2). Despite the greater proportion of respondents targeting gophers in SFV, the profile of target species was not significantly different between the two areas (Pearson's Chi-square, $p < 0.37$).

Most households applied rodent control themselves in both SFV (62.5%, 25 of 40) and BA-HH (60%, 9 of 15). Gardeners also applied rodent controls (SFV = 17.5%; BA-HH = 6.6%). In BA-HH area, 28% of respondents hired a pest control company but also applied chemicals themselves.

Figure 3. Types of chemical rodenticide used on residential properties in two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents were able to select multiple answers. Active ingredients from brand name products are listed.

The most commonly reported chemicals in SFV were fumigants, whereas SGARs (active ingredient brodifacoum) were most common in BA-HH (Figure 3). For both areas together, respondents who used anticoagulant rodenticides either could not recall a specific brand name, or if they did, 12 of 13 products uses reported were second-generation (i.e., brodifacoum or bromadiolone). The profile of rodenticides used in the two areas differed substantially (Pearson's Chi-square, $p < 0.09$), with the fumigants being used in SFV and not in BA-HH.

In both locations, households that indicated use of anticoagulants, respondent application of it ranged from monthly to twice per year or variably. From the categories provided on the survey, 10 SFV and 5 BA-HH respondents reported placing SGARs outside away from walls up to 300 and 100 feet away from buildings respectively (Figure 4). Homeowners observed dead rodents (target species) outside after chemical application in both study areas. The median distance category was 1–10 feet for both SFV and BA-HH, and ranged upwards to 30–100 feet away. Of the respondents who placed SGARs outdoors, four observed dead animals outdoors. One homeowner placed a product only *inside* his garage and subsequently found dead animals both inside and outside of the structure.

Figure 4. Distribution of anticoagulant rodenticide application outdoors on residential properties in two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents were able to select multiple answers.

In SFV, 66% of participants (4 of 6) admitted knowing that chemicals used in rodent control, as well as anticoagulants, might be affecting local wildlife. In BA-HH, 35% homeowners (7 of 20) knew about effects of SGARs on wildlife. Five people did not know and 8 people did not answer the question.

Surveys of Pest Control Operators (PCOs)

Five of 23 PCOs contacted in SFV responded to our survey. All 5 PCOs stated that they primarily control mice and rats, and use snap traps. Four also responded that they use chemical baits, and 2 used exclusion techniques. For those that used chemicals, 3 used SGARs and 2 used available first generation anticoagulants.

All PCOs stated that the main reason they are contacted is because of indoor rodents; two of those PCOs also stated as many calls about rodents in outdoor landscaping. All 5 companies inform homeowners about products used; 2 companies inform homeowners about locations of traps or bait. All PCOs reported placing rodenticides within 1 foot of fences and buildings, while one each reported placement up to 60 feet from buildings.

Only 2 of 37 (5.4%) PCOs from the BA-HH area responded. Neither company used chemicals; both used snap traps and exclusion techniques.

DISCUSSION

Homeowners reported applying rodenticides in ways that are prohibited by package instructions. Thus, this is a probable pathway for transfer of SGARs to other wildlife. Because our study areas

are known to have nearby carnivore populations, we can speculate that wildlife may encounter the poison directly, and, more importantly, can encounter as contaminated prey animals, alive or dead.

The two compounds (brodifacoum, bromadiolone) most frequently detected by Riley et al. (2007) in mammalian carnivores were the same most frequently reported as used by respondents in our survey (Figure 3). Similarly, bromadiolone and brodifacoum were the two most common compounds found in more than 100 mountain lions tested from around the state of California (R. H. Poppenga, personal communication, December 8, 2010). Respondents also reported use of the first-generation anticoagulant poison diphacinone, but this chemical is also highly toxic to birds and mammals (Rattner et al. 2011).

Entire housing developments in our study area may contribute to secondary poisoning through systematic use of SGARs. One homeowner noted on their returned survey that her HOA had applied numerous bait stations containing difethialone around homes for many years, but has since changed to a more environmentally friendly method.

We speculate that homeowners with pets may be more wary of using chemical rodenticides; one homeowner stated that “[We] used the poisons before but not anymore because of the cat and also the hawks.” This was consistent with Morzillo and Mertig’s (2011a) suggestion that concern about rodenticides affecting wildlife was the most significant predictor of the potential for residents to change their pest control behavior.

Stricter U.S. Environmental Protection Agency regulations on pesticides took effect in June 2011 (U.S. Environmental Protection Agency 2008). These regulations significantly reduce the availability of SGARs to homeowners by prohibiting their sales in grocery stores, drug stores, and hardware stores. They also specify that these products must be sold in a preloaded bait station or in bulk quantities. Such changes are intended to decrease the potential for exposure of non-target wildlife (U.S. Environmental Protection Agency 2008).

The EPA’s mitigation measures contain an implicit assumption that homeowners are more likely than a pest control operator to misuse products, which is consistent with our data (even with our small sample size). If residential users do not follow directions carefully when products are available, reducing availability of SGARs may be an effective action to reduce improper use and subsequent effects on wildlife. It may be beneficial to re-survey homeowners after the effective date of new restrictions to determine if rodent control practices have changed and whether these restrictions are an effective way to reduce homeowner use of SGARs. Licensed applicators may account for a great deal of use of these chemicals, and the use of their services may increase with decreased availability of products to homeowners. Currently, 58% of residents near our study area report self-applying rodent control products (Morzillo and Mertig 2011b), so the EPA rule change may have a substantial effect.

The geography of our study sites limited our ability to distribute fliers easily, and may have contributed to low response rate. Some locations were gated or depositing fliers was not allowed. The homeowner or upkeep staff may not have seen the flier or interpreted it as junk

mail. Therefore, our challenges revealed a difficulty with trying to recruit participants living in affluent areas by media other than mail or telephone.

Some potential biases were unavoidable. First, the title and purpose of the survey may have caused participants to make assumptions about what responses were expected by surveyors. Second, those who are not using rodent control may have felt it unnecessary to participate. Conversely, the UCLA Institute of the Environment as the research group may have led participants choose “environmentally friendly” answers, or to not respond in general. The probability of response may also have been affected by unwillingness to report behavior that might be construed as being irresponsible or illegal and those who have a low level of environmental awareness or interest may not respond either, although eligibility to win a gift certificate was provided as incentive for participation to offset this tendency. Nevertheless, the results do show that off-label use of SGARs does occur, which justifies further investigation.

Future studies should attempt to obtain a greater response rate from both homeowners and PCOs. Regardless, this research yielded: (1) the finding that off-label use was common among respondents, while our very small sample of PCOs reported following guidelines, and (2) information about logistics of surveying by an online questionnaire with participants solicited by fliers delivered to their homes. Although Morzillo and Mertig (2011a, b) had previously investigated what type of chemical products were used and where products were applied, they did not report on whether compounds were first- or second-generation ARs or how exactly residents applied the chemicals. Further research using mailed surveys and multiple follow-up techniques could be used to confirm and generalize the results of our findings and should be expanded to further explore the influence of attitudes about wildlife and potential non-target poisoning (e.g., pets) on SGAR use. Such an approach could also track the effects of the EPA’s rule change. It would also be useful to add questions about where residents buy their rodent-control products and inquire about the factors that influence the choice of product. Our results have provided preliminary results that could aid in developing such expanded survey instruments.

To mitigate poisonings now, we recommend outreach programs discussing the potential effects chemical products on wildlife. Near our study area, Morzillo and Schwartz (2011) found relationships between rodent control and resident proximity to natural areas. Thus, for example, property owners next to natural areas and who control rodents also might be gently reminded to review product application directions. Awareness or outreach may solve the problem. Yet, at least two respondents who claimed to know about the adverse effects of SGARs on wildlife also reported using them, so regulation will still be key to any approaches to reduce exposure of non-target species to SGARs.

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APPENDICES

Appendix A: Survey Questionnaire

1. Information sheet for consent to participate in a research study. By reading and accepting this questionnaire, I am agreeing to participate in this study.
 - ☐ Yes, I agree to participate in this study.
 - ☐ No, I do not agree to participate in this study.
2. Do you currently live in [survey area]?
 - ☐ Yes
 - ☐ No
3. Do you live in a single-family residence?
 - ☐ Yes
 - ☐ No
4. Do you live south of Ventura Boulevard?
 - ☐ Yes
 - ☐ No
5. Has any form of rodent control been used on your property in the past year?
 - ☐ Yes
 - ☐ No
6. What animals are/were you trying to control for? (check all that apply)
 - ☐ Mice
 - ☐ Rats
 - ☐ Gophers
 - ☐ Moles
 - ☐ Squirrels
 - ☐ Opossums
 - ☐ Raccoons
 - ☐ Skunks
 - ☐ Other _____
7. What caused your household to begin controlling these animals on your property? (check all that apply)
 - ☐ Observed animals indoors
 - ☐ Observed animals outdoors
 - ☐ Damage observed to own structures
 - ☐ Damage observed to neighbor's structures
 - ☐ Damage observed to own landscaping (including garden, lawn, etc.)
 - ☐ Damage observed to neighbor's landscaping (including garden, lawn, and etc.)
 - ☐ Preventative use
 - ☐ Part of routine treatment by hired company
 - ☐ Other _____
8. Who applied the rodent control? (check all that apply)
 - ☐ Member of household
 - ☐ Pest control company

- Gardener/landscape company
- Not sure
- Other _____

9. If you answered with Pest Control company, please specify which company:

- Don't remember
- Please specify: _____

10. If you answered with Pest Control company above, did they provide you with information about the products they applied?

- Yes
- No
- Not sure
- Not applicable

11. Which, if any, of the following non-chemical rodent control methods have been used on your property in the past year: (check all that apply)

- Snap traps
- Glue boards
- Live traps
- Shooting
- Electricity (i.e. rat zapper)
- Ultrasound deterrents
- Preventative methods (e.g. securing access points, cutting vegetation)
- Don't know
- None

12. [Brand images] Which, if any, of the following brands of chemical rodent control methods have been used on your property in the past year: (check all that apply)

- d-con
- Tomcat Liquid
- Tomcat Bait Stations
- Tomcat Quickstrike
- Tomcat Pellets, Blocks, and Trays
- Moletox
- Wilco Baits
- Victor Fast-Kill
- Victor Multi-Kill
- Ratol
- FirstStrike
- Rodetrol
- Other fumigants (e.g. gas canisters)
- Other nerve agent (e.g. Bromethalin)
- Zinc phosphide
- Don't know
- None
- Other

13. If chemical rodent control is applied on your property, how often is it applied?

- Approximately every month or more often

- Approximately every other month (6 times per year)
- Approximately every four months (3 times per year)
- Approximately twice a year
- Approximately once a year or less often
- Other _____

14. If chemical rodent control is applied on your property, in what locations INSIDE of structures is it used? (check all that apply)

- Basement
- Crawlspace
- Attic
- Another location within home
- Garage
- Outbuilding
- Not applied
- Other _____

15. If chemical rodent control is applied on your property, in what locations OUTSIDE structures is it used? (check all that apply)

- Along walls of any building (within 1 foot)
- Between 1 and 10 feet from any building
- Between 10 and 30 feet from any building
- Between 30 and 100 feet from any building
- Between 100 and 300 feet from any building
- More than 300 feet from any building
- Not applied outside

16. Has anyone in your household found dead animals at the following locations INSIDE structures after chemical rodent control methods have been applied? (check all that apply)

- Basement
- Crawlspace
- Attic
- Another location within home
- Garage
- Outbuilding
- Not applied
- Other _____

17. Has anyone in your household found dead animals at the following locations OUTSIDE structures after chemical rodent control methods have been applied? (check all that apply)

- Along walls of any building (within 1 foot)
- Between 1 and 10 feet from any building
- Between 10 and 30 feet from any building
- Between 30 and 100 feet from any building
- Between 100 and 300 feet from any building
- More than 300 feet from any building
- Not applied outside

18. Are you aware that chemicals used for residential rodent control may be affecting wildlife in your area?

- Yes
- No

19. Does your household have a pest with access to the outside?

- Yes
- No

20. Does anyone under 18 years old live in your household?

- Yes
- No

21. How large is your property?

- Less than 5,000 square feet (0.1 acre)
- 5,001–7,000 square feet (0.11–0.16 acre)
- 7,001–10,000 square feet (0.17–0.23 acre)
- 10,001–21,779 square feet (0.24–0.49 acre)
- 0.5–1 acre
- More than 1 acre

22. What is your annual household income?

- Less than \$50,000
- \$50,000 to \$75,000
- \$75,001 to \$100,000
- \$100,001 to \$150,000
- \$150,001 to \$200,000
- \$200,001 to \$300,000
- More than \$300,000

23. What is the highest level of education you have completed?

- Less than high school
- High school or FED
- Vocation or trade school
- Some college
- Associate's (2 year) degree
- Bachelor's (4 years) degree
- Graduate or professional degree

24. Please specify your year of birth.

25. What is your ethnic background?

- White/Caucasian
- Black/African American
- Asian/Pacific Islander
- Hispanic/Latino
- Other _____

Thank you for your participation!

If you wish to be entered into a drawing for a \$50 Best Buy Gift Card, please email your contact information to [student email]. Your email will not be associated with your responses to the survey and we won't share your email with anyone or send you messages.

Appendix B: Door-to-door Recruitment Flier

UCLA Institute of the Environment Senior Environmental Science Practicum

Methods of Rodent Control in Residential Areas Surrounding the Santa Monica Mountains

The purpose of the survey is to study the reasons for and the use of rodent control methods around the Santa Monica Mountains. The survey is expected to last only 5 – 10 minutes, and your participation is completely voluntary. You may exit at anytime without any consequences, and all data collected in this survey will be kept confidential.

Upon completion of the survey, you will have the option to email us to enter yourself in a drawing to win a \$50 Best Buy gift card.

The link for the survey is as follows: **[website]**.

You will be directed to a UCLA Institute of the Environment Website. Please click on Rodenticide Usage Study to participate in the survey. The deadline to participate in the survey is **[date]**

If you have any questions, feel free to contact **[name]** at **[email]**, or Dr. Travis Longcore, our faculty advisor, at longcore@ucla.edu. Thank you for your time.

Appendix C: Pest Control Company Interview Questionnaire

1. What areas does your company currently service?
2. How does your company control for rodents?
 - 2a. If you use chemical rodent control, which chemicals does your company use?
 - 2b. If you use physical rodent control, which methods does your company use?
3. Does your company control for _____?
 - Mice
 - Rats
 - Gophers
 - Moles
 - Squirrels
 - Opossums
 - Raccoons
 - Skunks
 - Other _____
4. Do your customers tell your company why they need rodent control?
 - If so, what are the main reasons you hear?
5. What information does your company provide to customers regarding rodent control?
6. How often do you apply/reapply rodenticides at an average household?
7. Does your company apply rodent control inside structures?
 - If so, where? (Garage, basement, crawl space, attic, etc.)
8. Does your company apply rodent control outside structures?
 - If so, at what distances from buildings?